MER — [illegible]

Oral Rinehart
J. A. Swartout - 5

UNITED STATES
ATOMIC ENERGY COMMISSION

Copies forwarded by JAS to
K. Z. Morgan
S. Auerbach
W. H. Jordan
3/7/60

IN REPLY REFER TO:

ORB:CSS

Oak Ridge, Tennessee
March 3, 1960

Union Carbide Nuclear Company
Post Office Box P
Oak Ridge, Tennessee

COPY FORWARDED BY C. E. CENTER

Attention: Mr. C. E. Center, Vice President

Subject: PROPOSED CLINCH RIVER RESEARCH PROGRAM

Gentlemen:

Reference is made to J. A. Swartout's letter dated November 13, 1959, on the above subject, and to our letter of January 7, 1960, on the matter of consultants for the Ecology Section's program at ORNL in connection with the Clinch River Studies.

The Division of Biology and Medicine, Headquarters, has advised us that they are appreciative of the opportunity to participate in the meetings relative to the Clinch River Study, and they plan to continue to be represented. DBM requests that it be clearly understood that the Biology and Medicine (Program 6000) funds allotted are for ecological research only and should not be utilized for other phases of the proposed river program. It is expected that the ecological research part of the river study will be developed with advice from investigators such as those suggested in our letter of January 7, 1960.

The above comments of the Division of Biology and Medicine are for your information and any action that you deem appropriate. We wish to be kept informed of significant advances in the review of your program with the proposed consultants in order that we may keep DBM apprised of developments.

Your cooperation is appreciated.

Very truly yours,

E G Wende
for S. R. Sapirie
Manager
Oak Ridge Operations

CC: C. L. Dunham, HQ
J. A. Lieberman, HQ
R. C. Armstrong
H. M. Roth

MER file
[illegible]

Oral Rinehart
J. A. Swartout - 5

UNITED STATES
ATOMIC ENERGY COMMISSION

Copies forwarded 1-11-60:
W. H. Jordan
K. Z. Morgan (2)

IN REPLY REFER TO:

ORB:CSS

Oak Ridge, Tennessee
January 7, 1960

FORWARDED BY
C. E. CENTER

Union Carbide Nuclear Company
Post Office Box P
Oak Ridge, Tennessee

Attention: Mr. C. E. Center, Vice President

Subject: USE OF ECOLOGY CONSULTANTS BY ORNL -- ACTIVITY 6480, ENVIRONMENTAL SCIENCES RESEARCH

Gentlemen:

Reference is made to the letter from J. A. Swartout of ORNL to Herman M. Roth on November 13, 1959, subject "Proposed Clinch River Research Program", and to the meeting held at ORNL on December 18, 1959, for establishment of an inter-agency steering committee on river studies.

On the occasion of the December 18th meeting, representatives of the Environmental Sciences Branch, AEC Headquarters, discussed with Mr. E. G. Struxness the desirability of utilizing advisory services of seven consultants concerning the Ecology Section's program at ORNL for the Clinch River studies. Such consultants would be provided to ORNL at the expense of Carbide for a period not to exceed two days. It was agreeable to Mr. Struxness that the selected group of consultants be convened at ORNL.

The suggestion has been made by AEC Headquarters that the Laboratory consider, as consultants for this one-time advisory review, Drs. A. D. Hasler of the University of Wisconsin, Bostwick H. Ketchum of the Woods Hole Oceanographic Institute, Walter Chipman of the Beaufort Laboratory of the Bureau of Commercial Fisheries, U. S. Fish and Wildlife Service, Richard F. Foster of the Hanford Laboratories of General Electric, Allyn Seymour of the University of Washington, Howard T. Odum of the University of Texas, and David Carritt of the Chesapeake Bay Institute. With the exception of Dr. Odum, these names were discussed with Mr. Struxness at the meeting.

We shall appreciate your consideration of the above suggestion. We understand that ORNL feels the additional consultation would be most useful prior to the meeting of the Steering Committee on the proposed Clinch River

Study to be held on January 21-22, 1960. We concur in the proposed consultation. Thus we suggest you proceed to obtain the services of these consultants in number and at a time you believe advisable and appropriate. There are no additional funds available for these services or for conduct of the program.

Your cooperation is appreciated.

Very truly yours,

E G Wende

for S. R. Sapirie
Manager
Oak Ridge Operations

CC: C. L. Dunham, HQ
Joseph A. Lieberman, HQ
R. C. Armstrong
Herman M. Roth

Standard Form No. 64

Office Memorandum • UNITED STATES GOVERNMENT

TO : C. L. Dunham, Director, Division of Biology and Medicine, Headquarters

DATE: December 8, 1959

Copies forwarded 12-14-59: W. H. Jordan, K. Z. Morgan

FROM : S. R. Sapirie, Manager, Oak Ridge Operations

SUBJECT: CLINCH RIVER STUDY, OAK RIDGE NATIONAL LABORATORY

SYMBOL: ORB:CSS

Attention: John N. Wolfe.

Reference is made to our memorandum, dated November 25, 1959, addressed to Frank K. Pittman, Director, DRD, copy of which you received, subject as above.

With the above-referenced memorandum we transmitted ORNL's document entitled "Plan for Clinch River Study". The plan outlines work proposed by ORNL for a comprehensive river study of physical, chemical and biological aspects of the dispersal and fate of radioactive materials discharged into the Clinch River.

Aquatic ecology studies are a part of the broad river-study program. We enclose two copies of a letter from the Oak Ridge National Laboratory under date of November 23, 1959, setting forth the proposed ecological work on the Clinch River in more detail than contained in the document "Plan for Clinch River Study" which we also enclose. It will be noted that appropriate attention will be paid to the uptake and burden of radionuclides in the aquatic organisms as well as to other aspects of basic limnological investigation. It is hoped that mutual-interest services and advice will be obtained from state agencies and from the TVA, USPHS, USGS and other appropriate Federal bodies. A general discussion of the program with agency representatives and with representatives from the DRD Environmental and Sanitary Engineering Branch will be held at the Laboratory on December 18, 1959.

We will appreciate any comments or recommendations that you might have on the enclosed letter covering ecological objectives and on the document "Plan for Clinch River Study". The estimated man power levels and cost estimates provided are proportional parts of the current FY 1960 and FY 1961 budget under Activity 4452, Waste Disposal Development, River Studies phase, and Activity 6480, Environmental Sciences Research, ORNL.

E. A. Wende
for S. R. Sapirie

Enclosures:
1. Ltr JAS to HMR dtd 11/23/59. (2)
2. Clinch River Study Proposal.

CC: G. F. Quinn, HQ
F. K. Pittman, HQ, w/encl.
R. C. Armstrong, ORO
R. J. Brown, ORO
C. E. Center, UCNC
H. M. Roth, ORO
C. A. Keller, ORO

CR

OAK RIDGE NATIONAL LABORATORY

OPERATED BY
UNION CARBIDE NUCLEAR COMPANY
UCC
POST OFFICE BOX X
OAK RIDGE, TENNESSEE

November 23, 1959

U. S. Atomic Energy Commission
Post Office Box E
Oak Ridge, Tennessee

Attention: Dr. H. M. Roth

Gentlemen:

Subject: PROPOSED ECOLOGICAL RESEARCH ON THE CLINCH RIVER AND FORECAST OF NEEDS.

The purpose of this letter is to outline the objectives, proposed program and needs of the Clinch River Ecological Study. The general aspects of the biological, physical, and chemical research on the Clinch River to be done at the Laboratory are contained in a letter and memorandum of November 13, 1959 from J. A. Swartout to H. M. Roth.

Previous biological investigations on the Clinch River have been limited to a single study of the uptake and concentration of radionuclides by fish (Knobf 1951, ORNL 1031) and algae (Lackey 1957, ORNL 2410). Routine monitoring by the Applied Health Physics group indicates the uptake and concentration of radioactive wastes on bottom sediments (Cottrell, W. D., ORNL CF 55-10-125, ORNL 2847; Garner, J. M. and O. W. Kochtitzky 1956, J. Sanit. Engr. Div., Proc. Am. Soc. Civil Engrs. Pap. 1051).

The general objectives of the ecological phase of the Clinch River study will be to determine: (1) the biological and closely related physical and chemical mechanisms which affect the distribution and fate of radionuclides in the flowing water environment; (2) the factors which contribute to the downstream transport of radioactive materials; (3) the equilibrium conditions below the confluence of White Oak Creek and the Clinch River and the rate of progression of this equilibrium in a downstream direction; (4) suitable methods for rapid assaying of the consequences of a nuclear accident contaminating a river, including development of techniques for the radiobiological assay of aquatic environments.

The river will be considered as separate compartments of flowing water with dissolved and particulate organic and inorganic materials, organic and inorganic bottom sediments and organisms for analysis of uptake rates and equilibria. This approach will provide information necessary to determine the capacity of the environment to absorb radioactive wastes and mechanisms of downstream transport. The basic information on stream ecology and radioactive pollution will be applicable to similar warm-water streams, particularly those in eastern U. S.

The ecological studies on the Clinch River will be conducted in a series of interrelated phases. It is anticipated that the work program will provide data applicable to concurrent and succeeding phases so that it will be possible to obtain a more complete understanding of the river as an ecological system. The work program for the next three years has been designed to permit the gradual development of field and laboratory investigations in a logical sequence dependent upon the availability of manpower, equipment and funds for radiochemical analyses.

Preliminary field work in FY 1960 will be directed toward the selection of study transects in the Clinch River so that random sampling methods may be used for bottom-dwelling organisms and sediments. A central composite sampling design patterned after those of G.E.P. Box will be used to test for homogeneity of the water mass in river cross sections. Members of the Mathematics Panel will be consulted to assure that reliable statistical methods will be applicable to all field and laboratory data. Periodic chemical analyses (Ca, Sr, CO_3, HCO_3, Cs, K, Fe, nitrogen compounds, etc.) of the river water will be started to characterize the aquatic environment. These data will be necessary to interpret uptake and cycling of radioactive isotopes under natural conditions.

Because the last survey for contaminated fish was made 11 years ago the Tennessee Fish and Game Commission and TVA will be approached this year to aid in a fish survey. If their help is obtained and sufficient funds for radiochemical analyses are available, another survey will be made this year.

Initial laboratory studies in FY 1960 will be concerned with determining the role of heterotrophic microorganisms in the uptake and cycling of radionuclides such as Sr, Cs, Ru, Co, and Zr-Nb. It will be necessary to compare uptake and release of the various isotopes from sterile and non-sterile media to separate the biological action of the microorganisms from the physical sorption. Investigations will be made of uptake by uncontaminated organic matter from contaminated solutions and release of radionuclides from contaminated organic matter into uncontaminated solutions. The role of microorganisms in the food chain is not known. It is possible that they become food for microorganisms feeding on organic detritus and it may be assumed that they release radionuclides from organic matter by decomposition but rate processes are not known.

By FY 1961 it will be possible to direct a major effort toward determining the budget of photosynthetically produced organic matter (primary producer trophic level) in the Clinch River. This level is considered the primary concentration point from which radionuclides enter the food chain. Since a portion of the organic matter is produced within the stream (autochthonous) and some is derived from the surrounding watershed (allochthonous) it will be necessary to distinguish between these two sources.

The autochthonous primary production will be determined by diurnal changes in the dissolved oxygen content of the river water mass (Odum, H. T., 1956, Limnol. and Oceanogr. 1:102-117). The diurnal oxygen determinations will be done at least once a week throughout the year and twice a week during the summer. The hourly changes in oxygen concentration will be correlated with the hourly changes in incident light intensity, light extinction in the water, phosphate, nitrate, and chlorophyll and with environmental factors of water temperature, current velocity and day length. These data will be entered on IBM cards for a multiple regression analysis to evaluate the effect of these factors on the primary production in the river.

The allochthonous primary production in the river, consisting largely of leaves, may be determined by direct measurements on the quantity of leaves accruing to the river. The addition of allochthonous organic matter from a small stream will be measured by screening Melton Branch and relating the quantity of leaf material washed into the screen to its watershed. The degradation of leaf materials will be studied in samples of organic detritus from bottom sediments and samples of particulate detritus in the flowing water. The particulate detritus will be separated from the river water by millipore filtering and centrifuging. It will be possible to account for algal cells in the particulate fraction either on the basis of chlorophyll content or through direct microscopic examination and measurement of algal cells. The difference between total particulate material and algal cells will be the non-living detritus.

In FY 1961 preliminary investigations will be made to determine the chemical composition of aquatic organisms for biologically important stable isotopes and body burdens of radionuclides. Particular attention will be paid to Sr, Ca, Co, Cs, K, and I. Studies of the food habits of organisms will be started so that each species may be placed in the proper position of the food chain. Organisms ingesting sediments are especially interesting because it is probable that the digestive processes within the guts of these organisms will change the capacity of the sediments to adsorb radionuclides.

By FY 1962 a large-scale field and laboratory operation is contemplated which should provide information on body burdens, uptake and excretion rates for the more important radionuclides present in aquatic organisms. Previous work will provide population estimates and then it will be possible to calculate species turnover rate for each radionuclide of importance. It should also be possible to locate indicator organisms which may be used to assess immediately the consequences of a radioactive spill involving the release of significant amounts of radioactivity into the environment.

Visiting investigators, particularly university personnel, are anticipated during the summers. Many of these people will have research programs outlined but others will be open to suggestion. Several short-term studies are listed which may be conducted by these individuals.

1) What is the role of emergent aquatic insects in removing radionuclides from water and transporting these to the terrestrial environment? The transport may occur through the insects dying on land (mayflies and caddis flies) or being eaten by insectivorous birds which subsequently defecate over land (Peredelskii, A. A. and I. O. Bogatyrev 1960, Izv. Akad. Nauk. Biol. Sec. No. 2, 186-192).

2) What is the budget of a particular element (Sr for example) in a reach of the river? By determining the quantity of an element entering and leaving a

certain segment of the river a gross estimate could be made of export or storage under the conditions existing.

3) What is the capacity of suspended river sediments to adsorb various radionuclides? The radioisotopes in solution may be added to river water and a partition coefficient between the dissolved and particulate phases could be determined.

4) What would be the effect of river fertilization on photosynthesis in a stream such as the Clinch River? Phosphates and nitrates are usually limiting factors for algal growth in aquatic environments. The ORNL adds significant amounts of nitrates, so added phosphate should produce a rapid growth of algae. Such a method may prove useful in coping with the removal of radionuclides from large volumes of wastes--either in the river or holding basins--since algae have been shown to concentrate some isotopes 100,000 times or more.

5) What is the effect of current velocity on photosynthesis by algae? The general statement is made frequently that current enhances algal growth either by supplying nutrients or by removing waste products. It is possible in the laboratory to vary concentrations of nutrients in the medium and current velocity so that there is a constant flux of nutrients past the organisms grown on a glass tube. By using an experimental design for optimum conditions it will be possible to evaluate the effect of current. A similar study is possible on the respiration of consumer organisms such as caddis flies or Diptera.

Assistance in attaining the objectives of the program may be obtained through cooperation with the U. S. Geological Survey, TVA, Tennessee Stream Pollution Control Board and the U. S. Public Health Service.

Estimated manpower needs and costs are as follows:

FY 1960	1 man year	$ 30,000	
FY 1961	2 man years	70,000	(including analytical chem.)
FY 1962	3 man years	100,000	(" " ")

The costs for FY 1960 and FY 1961 would be a proportional part of the over-all Ecological Research (AEC 6480) budget for those years.

Sincerely yours,

J. A. Swartout

J. A. Swartout
Deputy Director

JAS:SIA:db

cc: C. E. Center
W. H. Jordan
K. Z. Morgan
E. G. Struxness
S. I. Auerbach (20)
F. L. Parker
J. C. Hart
D. J. Nelson

X-847

INTRA-LABORATORY CORRESPONDENCE

OAK RIDGE NATIONAL LABORATORY

To: W. H. Jordan
Building 4500

November 23, 1959

Enclosed is a program letter for the ecological part of the Clinch River study. Both ORO and DBM, Washington, requested that we prepare a fairly detailed outline of the ecological phases of the study. This letter elaborates the general information contained in the memorandum of November 13 from J. A. Swartout to H. M. Roth.

S. I. Auerbach
Building 9711-1 Y-12

SIA:db

Enclosure

[illegible]

[illegible] Operations

SUBJECT: CLINCH RIVER STUDY, ORNL

Copies forwarded by [illegible]
[illegible] H. Jordan
K. Z. Morgan
S. I. Auerbach
J. C. Hart

COPY FORWARDED BY C&E CENTER

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SYMBOL: ORP:OSS

Attention: J. A. Lieberman.

Reference is made to discussions held at ORO and at ORNL on October 29 and 30, 1959, by Dr. J. A. Lieberman of your staff on the subject of a comprehensive stream study of the Clinch River by ORNL with cooperation of TVA and other agencies.

We enclose four copies of a letter from the Oak Ridge National Laboratory dated November 13, 1959, with accompanying copies of a document "Plan for Clinch River Study". The plan outlines work proposed by ORNL for a comprehensive river study of the dispersal and fate of radioactive materials that are discharged to the Clinch River, dilution, seasonal influences, settling, variation in concentration, and all factors important in health hazard and low-level aquatic waste disposal evaluation. We understand that the other agencies, i.e., TVA, USPHS, USGS, and the Tennessee State Department of Health, have an interest in cooperating with ORNL and can provide information from their own studies that will be of assistance to the Laboratory's program.

A meeting is planned for ORNL on December 18, 1959, at which the Laboratory, ORO, and agency representatives will discuss the plan of study and in general outline the areas of cooperative endeavor. Funds for support of the program of ORNL work are budgeted under Activity 4452, Waste Disposal Development, River Studies phase, and the ecological program, Activity 6480.

We will appreciate your comments and suggest [illegible] arrange with [illegible] and USGS for their representation at the December 18 meeting [illegible] are interested. [illegible] will contact TVA and the Tennessee State [illegible] Department of [illegible] regard to their [illegible] letter [illegible]

[illegible]

OAK RIDGE NATIONAL LABORATORY

OPERATED BY

UNION CARBIDE NUCLEAR COMPANY

UCC

POST OFFICE BOX X
OAK RIDGE, TENNESSEE

CR

November 13, 1959

U. S. Atomic Energy Commission
Post Office Box E
Oak Ridge, Tennessee

Attention: Dr. H. M. Roth

Gentlemen:

Subject: PROPOSED CLINCH RIVER RESEARCH PROGRAM

The Staff of the Laboratory's Health Physics Division has prepared a draft of a proposal outlining a comprehensive stream investigation of the Clinch River below the Oak Ridge National Laboratory. The purpose of the study would be to obtain information on the physical, chemical, and biological aspects of a flowing, fresh water ecosystem which is receiving low-level, liquid radioactive wastes.

We believe this proposal would be of interest to other agencies which have some jurisdictional or other interest in this area. We suggest that it would be in the interest of the Atomic Energy Commission to circulate this proposal among these agencies and to invite their critical comments, suggestions and possible participation.

Sincerely yours,

J. A. Swartout

J. A. Swartout
Deputy Director

JAS:SIA:ms

Enclosure

cc: C. E. Center
W. H. Jordan
K. Z. Morgan
E. G. Struxness
S. I. Auerbach
F. L. Parker
J. C. Hart

PLAN FOR CLINCH RIVER STUDY

Purpose

The purpose of the study of the Clinch River below Oak Ridge National Laboratory is to obtain fundamental information on the physical, chemical, and biological dynamics of a flowing, fresh water ecosystem which is receiving large volumes of low-level radioactive wastes. Information from a broadly conceived fundamental and applied program will have important implications for two major world-wide problems resulting from large-scale environmental contamination. These are:

1. What is the over-all diluent capacity of fresh water environments for an increasing continuous input of large volumes of low-level radioactive wastes?
2. What is the long-term indirect impact of radioactive contamination of such environments?

Objectives

This program has four general objectives, namely:

1. to determine the fate of radioactive materials currently being discharged to the river,
2. to determine and understand the mechanisms of dispersion of radionuclides released to the river,

system, and because of the integrated use of water and steam the flow at Norris Dam through the turbines might be zero, 3000, or 5600 cfs. If the flow were zero prior to start-up, then a solitary wave would be generated when the turbine gates were opened. This would also be true if two turbines were operating prior to shutting down one. The velocity of the wave depends in part upon the depth of water in the river and so would vary depending upon the water elevation at Watts Bar Dam.

The time of travel of water from Norris Dam to CRM 20.8 is about twice the time for the wave to travel. This assumes unstratified flow in the river which is not always the case. In the summer backwaters from Watts Bar Dam are warmer than the Clinch River water released from Norris Dam and cause the Norris water to flow under the pooled water, a stratified flow. The "duck under point" varies, depending upon conditions in the river, but commonly occurs at about CRM 12.6. It is evident that the Clinch River is a highly complex hydraulic system.

The Clinch River is used for fishing, swimming, water skiing, irrigation, drinking water, and industrial cooling. The river is also used for navigation, primarily coal barges, up to the K-25 steam plant at CRM 13. The use of the river will be materially increased if the proposed Melton Hill Dam at CRM 23.1 is constructed. This would entail important channel changes and increased velocities and lower temperatures in the river for some distance below the dam.

Radioactive Releases to the River

The Oak Ridge National Laboratory releases some radioactive material to White Oak Creek from the waste water treatment plant, earthen seepage pits, drainage of various reactor facilities, cooling water from the reactors, and storage from the bed of White Oak Lake.

White Oak Lake from 1943 to 1955 had been used as an impoundment for the wastes released from the Laboratory. This lake covered an area of 35 to 44 acres and had an average depth of 6 feet. Some of the wastes flowing from the Laboratory settled in White Oak Lake and were sorbed on the muds and silts. Eventually, equilibrium was reached in the lake between inflow and outflow of radioactive materials and the lake was drained. Now the wastes flow in White Oak Creek through the bed of White Oak Lake. The gates at the dam are still operative and will be used to form a lake for temporary storage if higher level wastes than normal should accidentally be discharged.

During the 10 years, 1948-1957, a total of 3600 curies have been discharged from White Oak Creek into the Clinch River. The major radioactive constituents have been the rare earths, strontium 89, strontium 90, cesium 137, and ruthenium 106. In addition, White Oak Creek discharges substantial quantities of nonradioactive chemicals, particularly nitrates. This chemical discharge and the slowing down and warming up of the Clinch River waters below White Oak Creek results in luxurious algal blooms in the nutrient-rich waters.

The Oak Ridge Gaseous Diffusion Plant and the Y-12 Plant also discharge wastes to the Clinch River. The wastes from the uranium processing at these plants, though of low activity, does increase the contaminant load of the river.

MPC Standards for Releases to the River

The present National Committee on Radiation Protection (NCRP) standards for drinking water used by the population at large do not necessarily apply to concentrations in the Clinch River, because the river is not used as a source for community drinking water supplies. It is also possible that fission products in the river in concentrations lower than these MPC (Maximum Permissible Concentrations) standards could be reconcentrated in the bottom sediments and the biota to such an extent that hazardous conditions might develop. Studies of the continuous discharge of radioactive materials will lead to an understanding of the proper use of the river to assimilate radioactive wastes without detriment to man or to the environment.

Continuous Release

The continuous discharge of radioactive material, by definition, will allow the physical, chemical, and biological environments to approach steady state conditions. The absorption and adsorption of the radioactive material by the suspended solids and biota will tend to decrease the concentration of radioactive material in the water. The physical processes of dispersal need not be considered, because they apply only to the beginning and end of the flows. The rest of the time simple dilution is all that occurs, provided the contaminant is uniformly mixed by the time it reaches the cross sections of interest. The monitoring of continuous discharges must include measurements of concentration in the biota, mud, and water. Water used for drinking, irrigation, and recreation should not exceed acceptable dosages to downstream users. Based on present knowledge from the public health viewpoint, the most important elements of the environment to be monitored are those which are directly involved in human food chains; namely, water, fish, and irrigated agricultural crops. It is necessary, of course, to study the entire food-web in order to determine concentration rates of transfer and turnover so as to deduce the relationships between these components of the food-web and the human environment in order to evaluate ecological effects in the environment as a whole.

The primary emphasis of the study of releases to the environment to date has been to ensure that the concentrations are below the maximum permissible concentrations (MPC) for drinking water recommended by the National Committee on Radiation Protection (NCRP). To insure this, the liquid wastes from ORNL are continuously sampled in White Oak Creek at the White Oak Dam and in the Clinch River at K-25, the Gaseous Diffusion Plant. The U. S. Geological Survey measures the amount of flow in White Oak Creek and in the Clinch River so that the concentration of wastes in the river, assuming complete dilution, is obtained. The daily samples at White Oak Dam are composited and counted for gross beta and gamma. A portion of the flow is brought past a GM tube, and the count rate telemetered back to the area control laboratory. If the count should be high, White Oak Dam would be closed until such time as the activity had decayed or some remedial action had been taken.

Weekly composite samples are analyzed radiochemically for plutonium. Monthly composite samples are analyzed radiochemically for strontium, cerium, ruthenium, iodine, zirconium, trivalent rare earths, niobium, barium, and cobalt. Once the radioactive materials pass out of White Oak Creek they then flow into the Clinch River and eventually into the Tennessee River. Each year the Laboratory has conducted a survey of the amount of radioactive materials in the Clinch and Tennessee River sediments. Water samples are also taken. The river bottom is sampled every 2 miles in the Clinch River and approximately every 10 miles in the Tennessee River and in its reservoirs. Fifty-foot intervals are used in the Clinch River cross sections. An average of ten readings and samples are taken per cross section in the Tennessee River and at Watts Bar and Chickamauga reservoirs. The gamma radiation of the bottom sediments in place is measured by 12 battery-operated GM tubes connected in parallel. Bottom sediments are also analyzed for their radiochemical constituents. A water sample is collected daily at Centers Ferry near Kingston, Tennessee, and composited for a three-month period. The composite is filtered and concentrated. The residue of suspended solids and the concentrate are analyzed for fission products to determine the level and composition of the radionuclides existing in the Clinch River waters.

The highest concentration of radioactivity in the river bottom sediments is about eighteen times background and is located about 12 miles below the confluence of White Oak Creek and the Clinch River where the velocities are slowed. The concentration of radioactive materials in the river sediments falls off very quickly after the first 20 miles and is only about twice background at 100 miles and approaches background at 150 miles downstream, though fission products are still detectable by sediment analysis. At this level it is difficult, if not impossible, to distinguish between fall-out and waste disposal contaminants. The level of radioactive contamination in the bottom sediments drops off rapidly below each dam in the Tennessee River, and increases again as the next dam is approached. This occurs because the water velocity decreases at the dam, and particles settle out.

Proposed Program

The existing program will be increased to such an extent that a budget of the radioactive material in the river can be established. It is necessary to determine what is already in the river, what is being added to the river, and what is leaving the river. This budget will require a more detailed analysis of the wastes leaving the Laboratory and a more detailed determination of the radioactive material in the water, mud, and biota. Additional sampling stations will be established on the river both upstream and downstream from White Oak Creek. These stations will be correlated with the TVA silt ranges.

The main sampling stations will be located upstream as far as the site of the proposed Melton Hill Dam and downstream as far as the entry of the Emory River, Clinch River Mile 4.4.

The construction of Melton Hill Dam will have an important effect on the velocities, temperatures, and sediment transport of the Clinch River. It is estimated that the temperatures of the Clinch River waters at White Oak Creek will be 5° F lower than at present. This could mean that the nutrient-rich White Oak Creek waters would float on the surface of the Clinch River a good deal of the time.

The changes in the channel of the river to accommodate the discharge from Melton Hill Dam will disturb present sediment distribution as well as change the areas of deposition. An immediate start in the river program will make it possible to watch the build-up of sediments in new areas and to determine the means and mechanism thereof.

Water samples will be taken to determine the radioactive and chemical constituents. The cross sectional distribution of the radioactive materials in the water phase will be determined.

The bed load movements will be investigated to determine the amount of deposited silts that are being resuspended and to evaluate the effect of high velocities upon resuspension of silts. Silt samples will be examined to correlate radionuclide uptake with mineral species. It is planned that the USGS Geochemistry and Petrology Branch will determine the mineral species.

The last survey of contamination of game fish in the Clinch River, made in 1948, sampled fish at two locations - one just below the White Oak Creek outfall and the second at Clinch River Mile 18 to 19 (about 6 1/2 miles below the outfall). No collections were made above the outfall. Of the radioactive fish collected in the river proper, all were well within MPC standards in operation at that time. It would be desirable to survey for radioactive contamination the game fish species above and below White Oak Creek. The extent of a fish survey would be governed by the information obtained on water and silt contamination and by the ecologic data.

The general objective of the ecological research on the Clinch River is to obtain an understanding of the steady-state chemical and biological composition of the Clinch River ecosystem. To obtain an understanding of the system:

1. The population densities, distributions, biomass and radionuclide concentrations in the major bottom-dwelling organisms, such as shellfish (clams), crustacea, and insects, will be determined.

2. The seasonal and annual composition and variation of the Clinch River above and below the White Oak Creek outfall will be characterized. This objective will involve selecting suitable segments of the river for detailed study and analyses. Measurements will include the chemical and radiochemical composition of both organic and inorganic phases of the river water. For example, nitrogen, phosphorus, carbonates, stable isotopes (strontium, iodine, potassium, calcium, etc.) as well as radioactive ones, temperature, and turbidity will be measured. Total oxygen and carbon dioxide will be measured to determine the gross primary productivity which is the total rate of photosynthesis in the flowing water mass.

3. The movement and rates of biological and chemical cycling of strontium 90, cesium 137, and other isotopes in the Clinch River, will be measured. This work would include field and laboratory studies on rates of uptake and turnover of isotopes by characteristic river organisms under steady and nonsteady state conditions and varying substrate conditions.

Intermittent Release

An intermittent release may be characterized as one in which physical processes in the stream play the primary role, while the biological and chemical processes are subordinate. In other words, the "slug" of radioactive material will pass through each cross section of the stream so rapidly that it will not come to chemical or biological equilibrium with the biota and sediments. For the sake of simplification, therefore, we may ignore the uptake and deposition due to chemical and biological processes and determine the dispersion of radioactive materials due only to physical processes.

Present Program

A series of small-scale tracer tests were run this past summer, 1959, as part of the training program for the AEC Radiological Physics Fellows. The tests were particularly concerned with hydraulic conditions at the mouth of White Oak Creek and background radiation measurements above White Oak Creek. Through the co-operation of the USGS, velocity and temperature profiles were obtained at the same time.

Two years ago tracer studies were run when TVA maintained steady flow in the river in order to determine the degree of reaeration of the Clinch River below Norris Dam.

Tracer-level tests were run on July 4-7 and July 9-13. The TVA maintained a steady flow in the Clinch River of 3000 cfs for the first test and 6000 cfs for the second test. On each test, 5 curies of I^{131} was injected into White Oak Creek at its confluence with the Clinch River. Liquid samples were taken periodically during the course of the test at Clinch River Miles 19.6, 17.8, 15.5, 14.0, and 13.1 (stations A, B, C, D, and E, respectively)(Fig. 1). Scintillation counters were used for measuring the concentration of radioiodine flowing past the sampling stations. Through a co-operative arrangement with the U. S. Geological Survey, the flow through this reach of the river was measured during the test. The velocity and temperature profiles at the sampling stations were also determined by the U. S. Geological Survey.

Additional liquid samples were collected downstream at Centers Ferry (CRM 4.4) and at the Kingston Steam Plant (Emory River intake). While the results have not been completely evaluated, preliminary studies of the first test at CRM 19.6 (station A) show clearly that complete dilution was not attained, under the river conditions existing during the time of the test. A definite temperature gradient existed (Fig. 2) causing the concentration profile shown in Fig. 3. The contaminated White Oak Creek water flowed below the surface waters of the Clinch River and remained close to the right bank, only gradually spreading across the river. Further downstream at station C, CRM 15.5, complete dilution was obtained.

<u>Proposed Program</u>

It is possible to determine dispersal patterns of intermittent releases by three methods:

<u>1. Analytical.</u>-- The purely analytical approach is based on the theories of fluid mechanics. Because of the inhomogeneities in the cross section, gradient and level of the stream, and the variableness in flow and temperature, simplifying assumptions must be made. The simplified equation and its solution is:

$$\frac{\partial^2 c}{\partial x^2} - \frac{v}{\alpha^2}\frac{\partial c}{\partial x} - \frac{(\lambda + N)c}{\alpha^2} = \frac{1}{\alpha^2}\frac{\partial c}{\partial t} \qquad (1)$$

$$c = \frac{M}{\sqrt{4\pi A\alpha^2 t}} \ \text{exponent} \ - \frac{(x - vt)^2}{4\alpha^2 t} - (N + \lambda)t \qquad (2)$$

where c is the concentration of the contaminant, M the mass of the contaminant, A the cross sectional area of the stream, α^2 the eddy diffusion coefficient, t the time after release of contaminant, x the distance from release point, v the mean velocity of the stream, N the river uptake coefficient, and λ the nuclear decay coefficient.

It is obvious that all the unknowns and uncertainties of the biological and chemical processes are lumped together in the river uptake coefficient.

2. Field Testing. -- It is necessary to run a series of field tracer tests, which is the second method of studying intermittent releases, with various isotopes to determine the river uptake coefficient and the eddy diffusion coefficient for the particular conditions under which the tests were run. The coefficients are obtained from the field test data by plotting the per cent of the contaminant passing each station on semilog paper versus time and from the slope determining the combined nuclear decay and river absorption coefficient. The eddy diffusion coefficient can be determined by multiplying the flow-through curves by the combined nuclear decay and river uptake coefficient to make the normalized area under the curve equal to 1. Then taking advantage of the fact that the flow-through curve is a skewed Gaussian curve, the eddy diffusion coefficient is found by use of the properties of the moment generating function to be equal to

$$\alpha^2 = \frac{x^2}{2} \frac{m_2}{(m_1)^3} \qquad (3)$$

where x is distance downstream from the dosing station, m_2 is second moment generating function about the origin, m_1 is first moment generating function about the origin. When average values for eddy diffusion and river uptake coefficients have been determined for a wide variety of conditions, then it should be possible using equation 2 to determine the contaminant flow-through curves. Without these experimentally determined values, the utility of the first method is relatively limited.

The problems of field testing, such as irregular flows, temperature changes, large man power and equipment requirements, and the necessity of many tests to obtain results under representative conditions, are manifold; however, it is the only exact method possible.

3. Model Testing. -- A third possible method is model testing where flow, temperature, and elevation can be varied easily over wide ranges and can be related to prototype once the model has been verified. A model is verified hydraulically to insure that the velocities and direction of flow are in proper agreement with the prototype. The model would also need to be verified in these tests for temperature distribution, as the density currents resulting from the variations in temperature play an important role in the dispersion of the radiocontaminants. The model would be scaled by the Froude number $\frac{v}{\sqrt{gl}}$ where v is velocity, g is gravitational acceleration, and l is distance, as the gravitational effects are more dominant than the viscous effects. The surface tension and elastic compression of the

water can be safely ignored in open channel tests. No model can, of course, reproduce the effects in the prototype, since the viscous forces, surface tension, and elastic compression do play a role in the flow regime. However, the major changes in concentration due to changes in flow, height, etc., can be measured with sufficient accuracy for engineering works.

The model is planned to cover the stretch of the river between White Wing Bridge, CRM 21.7, and Brashear Creek, CRM 9.9, a distance of 11.8 miles by river. The maximum depth of water in this stretch is only 30 feet. Therefore, it is necessary to use a vertically distorted model. Otherwise, if the model-prototype ratio were 1 to 1000, the depth in model would only be three-hundredths of a foot. At that maximum depth and at lower average depths, viscous effects and surface tension would become important in the model though not in the prototype.

At present it is planned to build a simplified model to determine the entrance conditions from White Oak Creek into the Clinch River. A series of small-scale tracer tests, including velocity and temperature measurements, were made to provide the data necessary to verify this simplified model. The larger model will be built in sections with the first section covering River Miles 21.7 to 19.8. If dispersion is complete by that station, then the rest of the model can be neglected. If testing shows that dispersion is not complete at Mile 19.8, then another section of the model will be built. If the horizontal scale were 1 to 500 then the total area covered by the field model would be 2560 square feet (40 feet by 64 feet).

Conclusion

The best solution to the intermittent test, and the continuous test as well, is a synthesis of all three methods, combined with the information developed by the study on the rates of uptake of the various isotopes by individual organisms, muds, and flora. Then it should be possible to use the model data, the field test data, and the ecological information to obtain the constants necessary for the mathematical model of the system and to calculate the flow-through curves of the contaminant for a wide variety of conditions. This is essentially the approach that was used to evaluate the water-borne hazards of the start-up of the N. S. Savannah at Camden, New Jersey (ORNL CF-59-9-9).

Program Fiscal Years 1960 and 1961

During the next two years it is proposed to implement the above overall plans by:

1. Year-round survey above and below the confluence of White Oak Creek with the Clinch River for radionuclide composition and concentrations in:

   a. Sediment samples which will be correlated with TVA silt ranges to determine the total radionuclide load in the sediments. Continuing surveys will check the build-up in these sediments and whether equilibrium is being reached. In particular, surveys will be made during periods of low and high flows to determine the effect of such flows on the total contaminant load.

   b. Water samples which will be taken as part of the limnological study to determine the activity and chemical distribution across the stream and downstream for the various river regimes. The temperature profile, turbidity, and diurnal oxygen curve will also be measured.

2. Fish collection at various points above and below White Oak Creek and analyses for radioactive content.

3. Quantitative plankton and bottom invertebrate analyses.

4. Tracer studies with releases occurring under a variety of river regimes.

5. Model testing of the reach of the river immediately downstream of White Oak Creek.

The above studies will be co-ordinated with the programs of the U. S. Geological Survey, Tennessee Valley Authority, Tennessee Stream Pollution Control Board, and the U. S. Public Health Service.

The estimated man power and dollar costs will be:

Year	Man Power	Costs
1960	3.3	$100,000
1961	5.0	150,000

These estimates include the man power and dollars supplied by the Waste Disposal Research and Engineering, Ecology, and Applied Health Physics Sections of the Health Physics Division to carry out their respective shares of the program.

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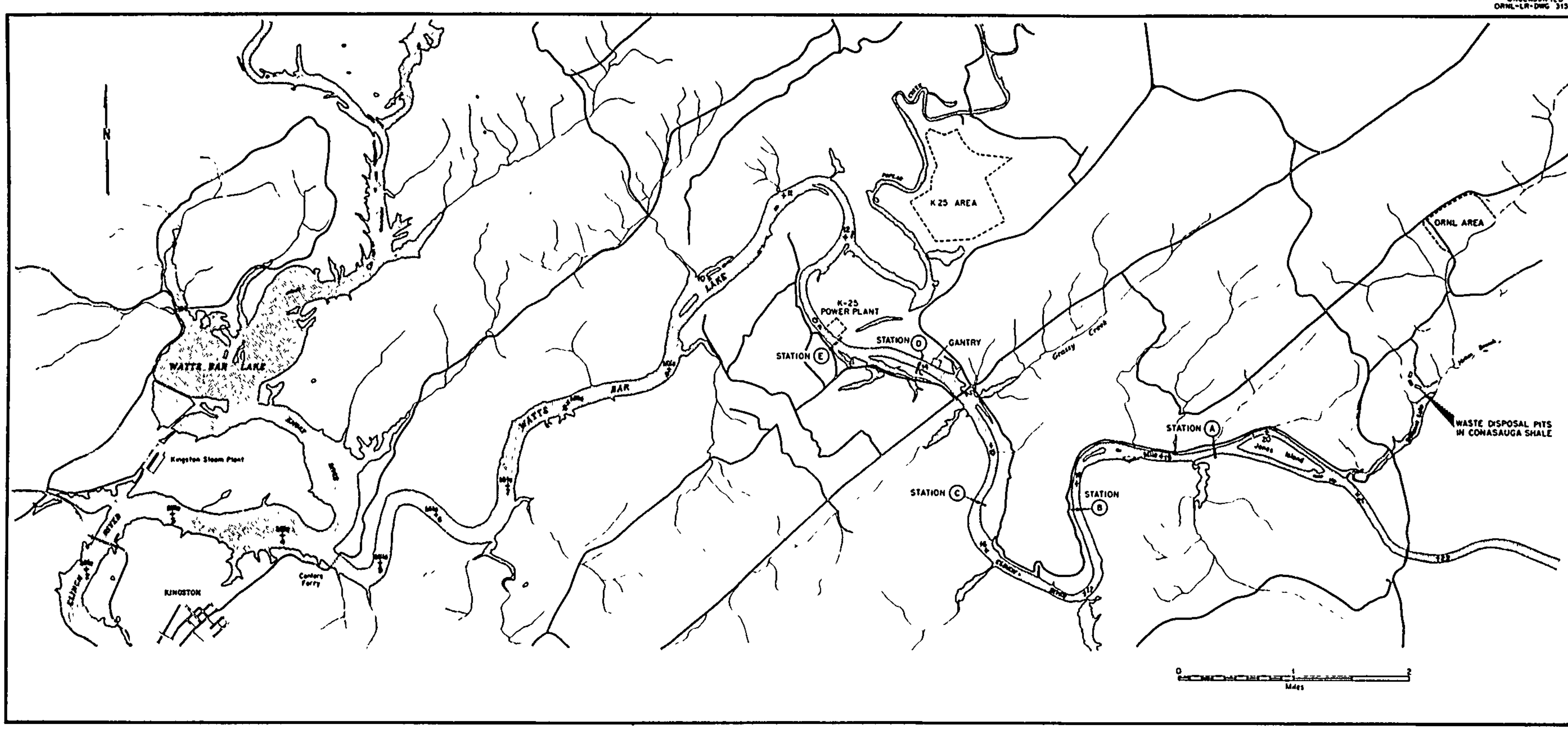

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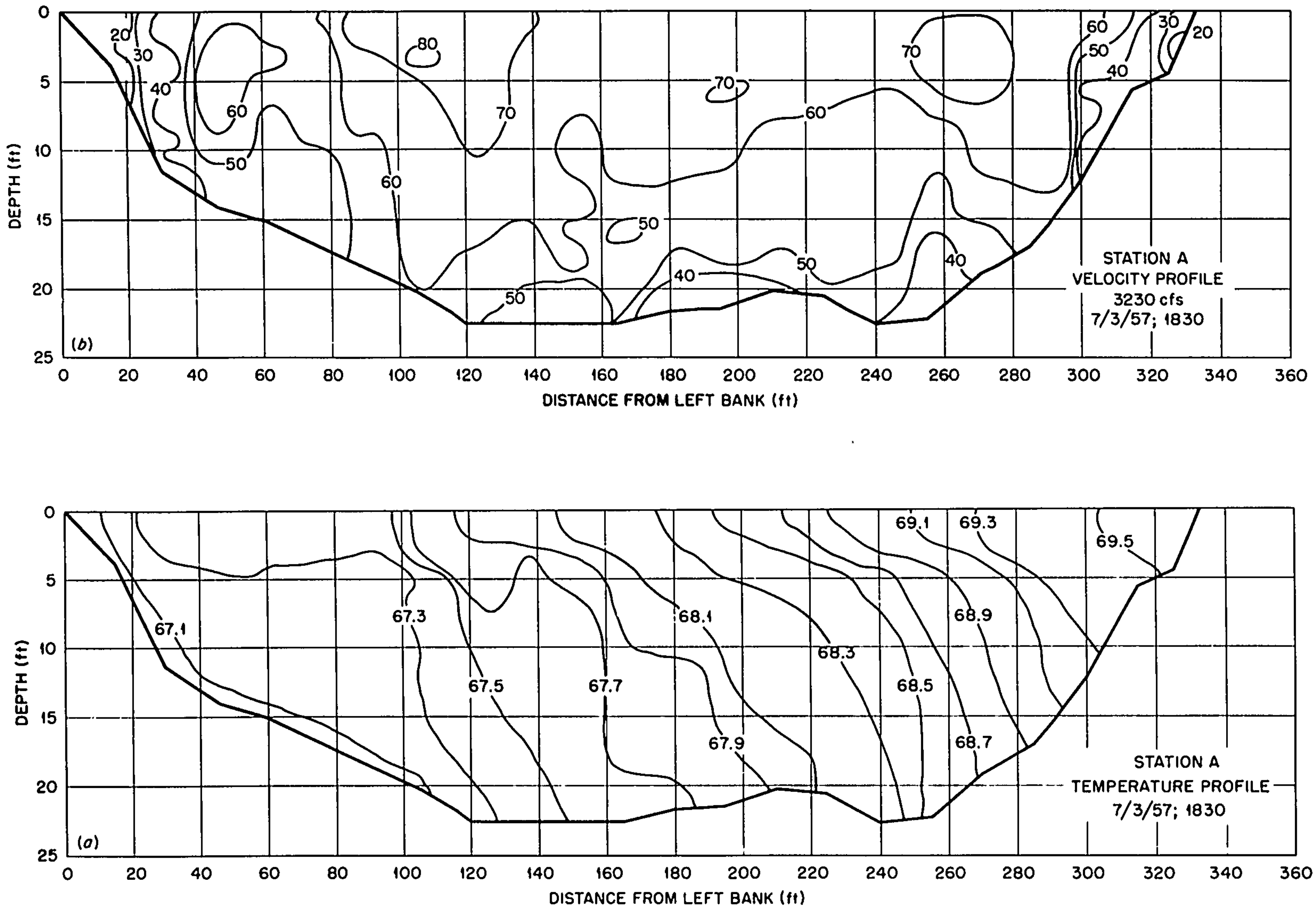

Fig. 2. Temperature (*a*) and Velocity (*b*) Profiles at Clinch River Mile 19.6, Test 1.

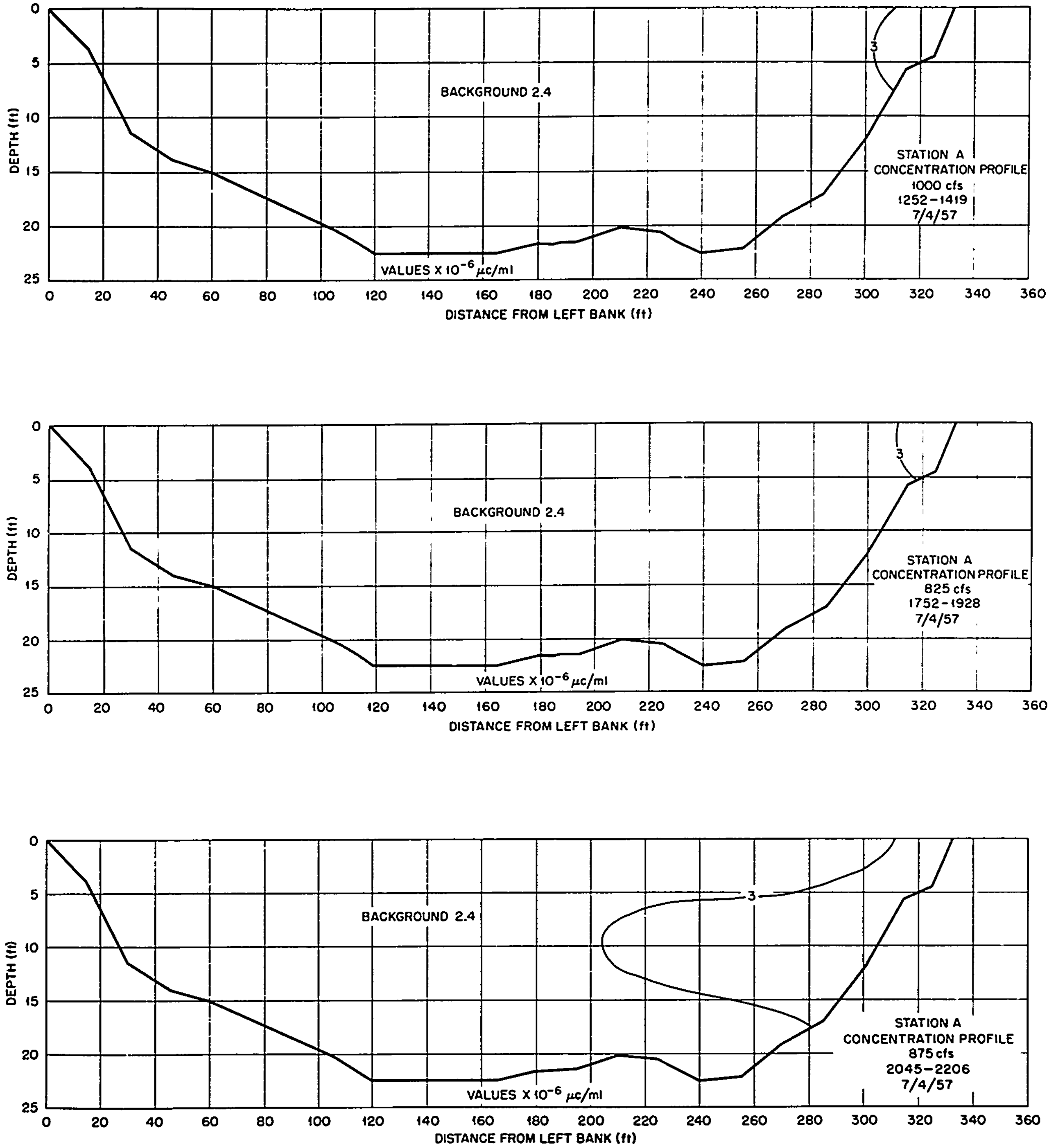

Fig. 3. Concentration Profiles at Clinch River Station A.

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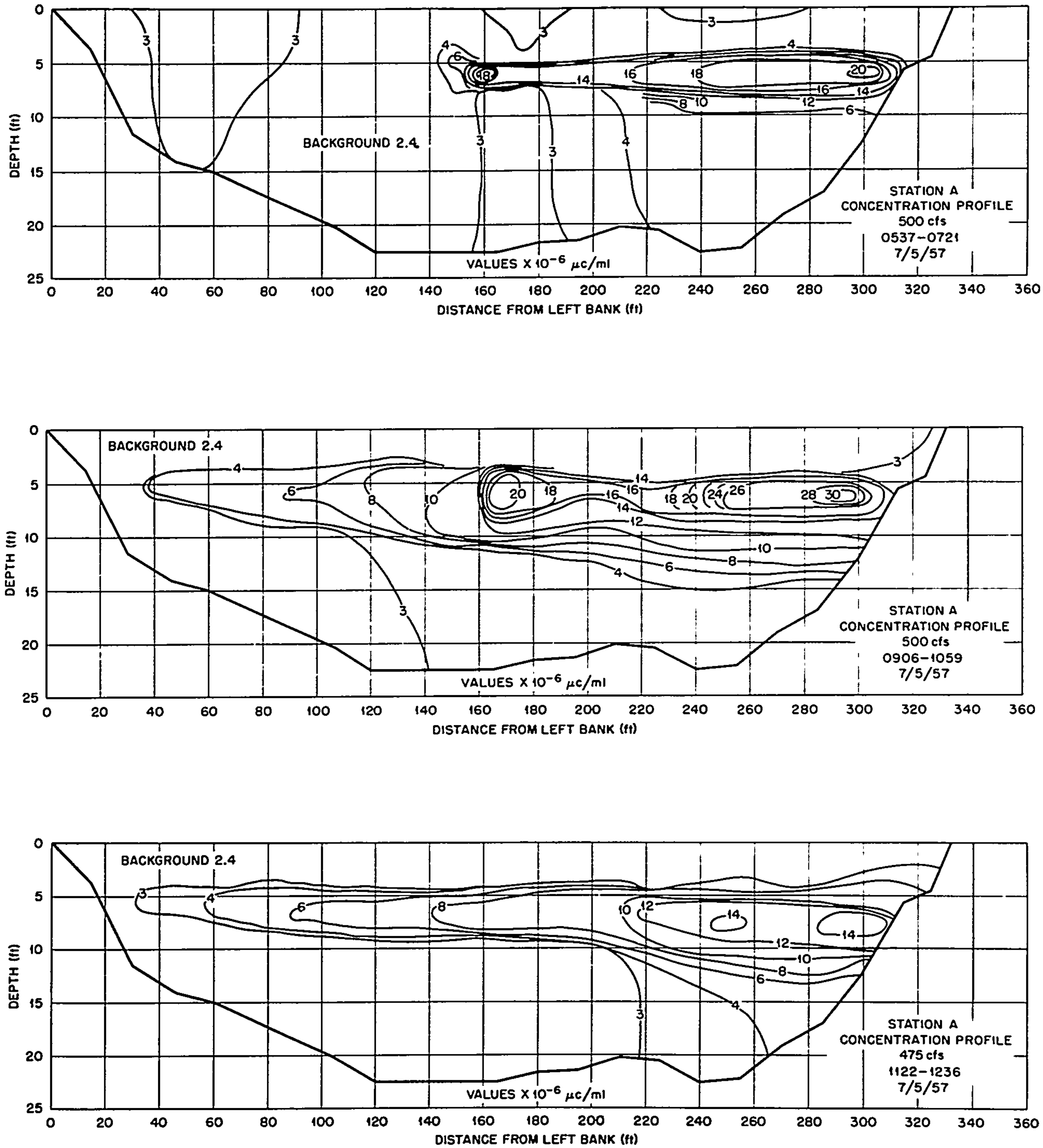

Fig. 3 (continued). Concentration Profiles at Clinch River Station A.

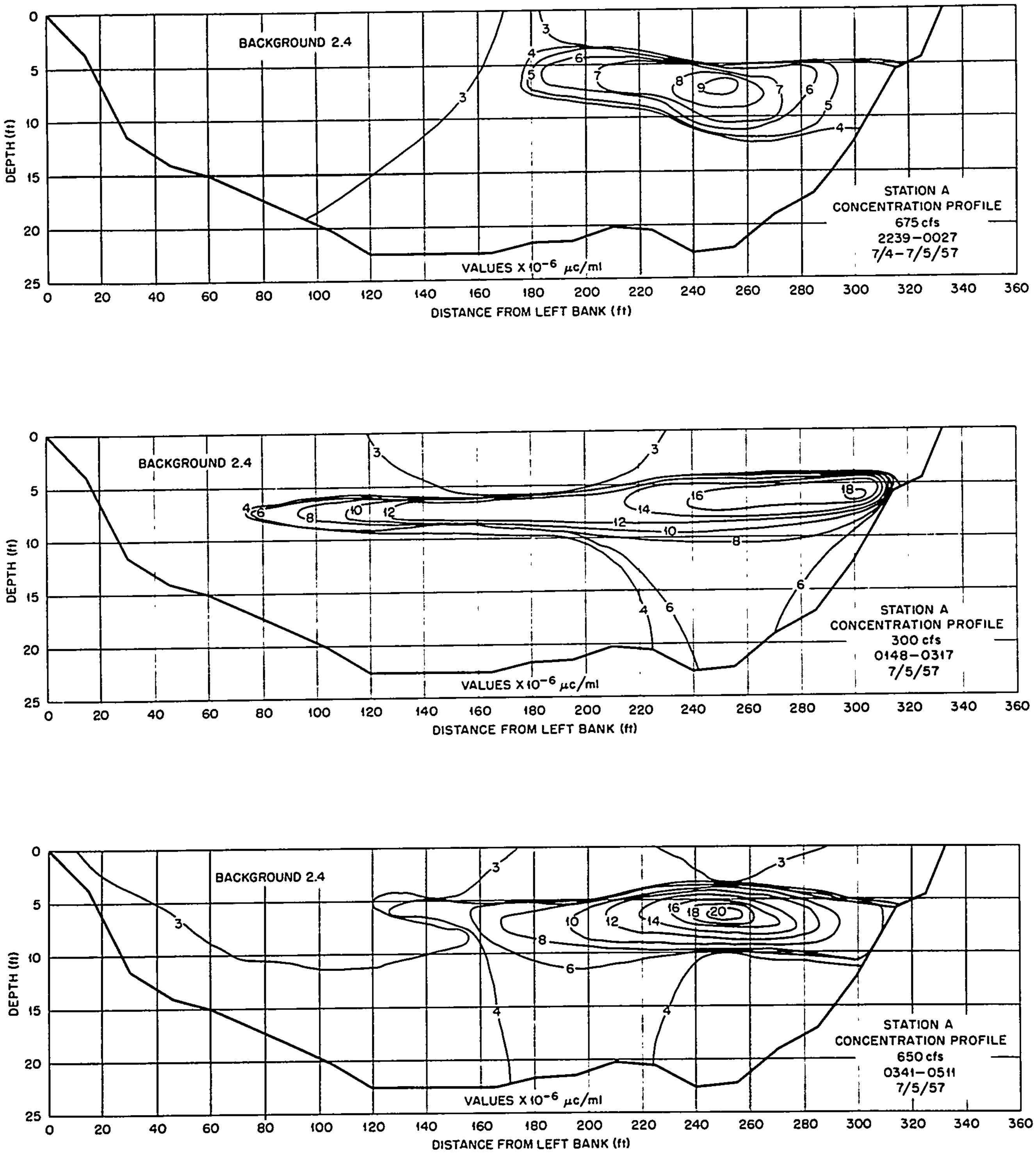

Fig. 3 (continued). Concentration Profiles at Clinch River Station A.

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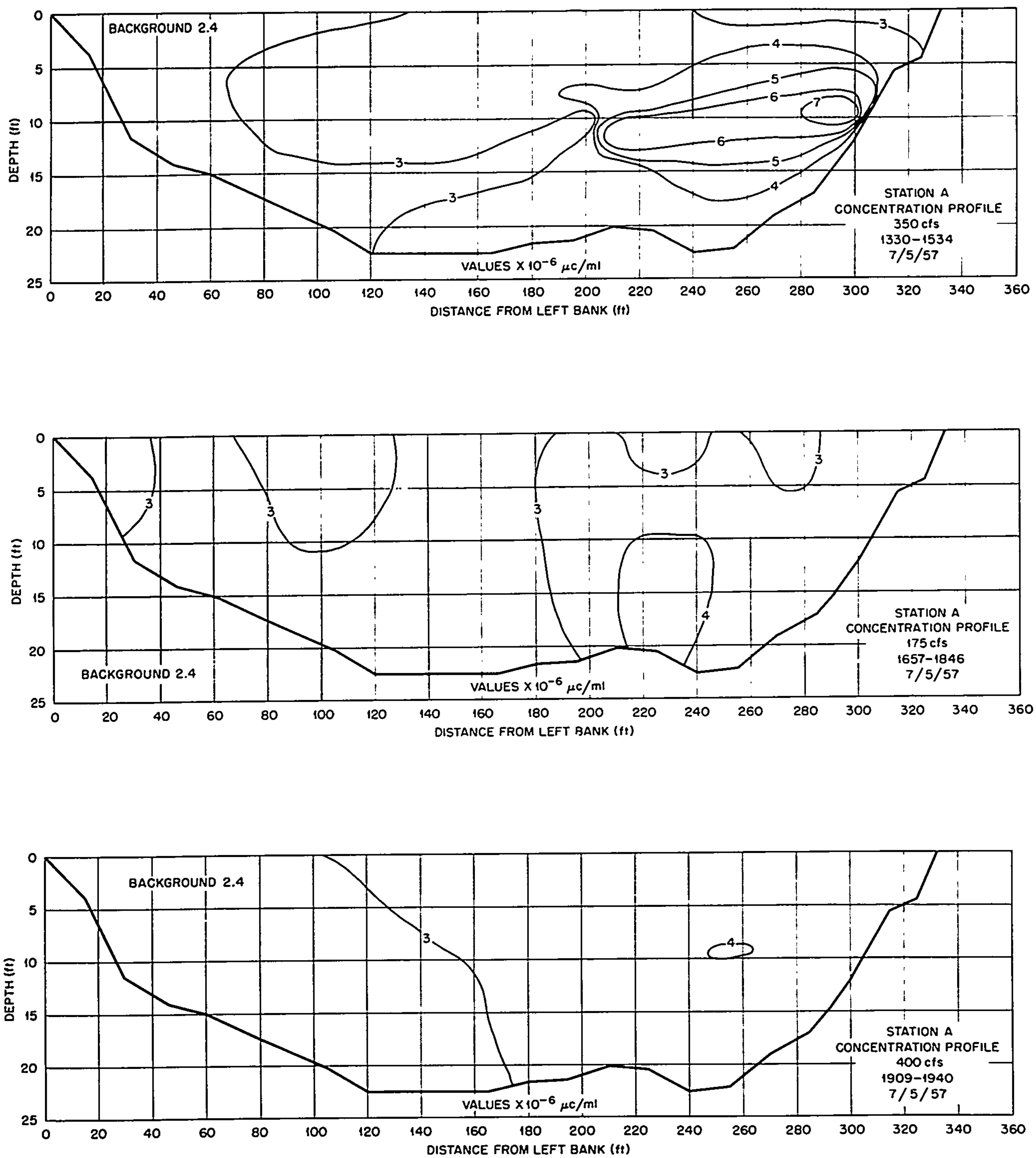

Fig. 3 (continued). Concentration Profiles at Clinch River Station A.